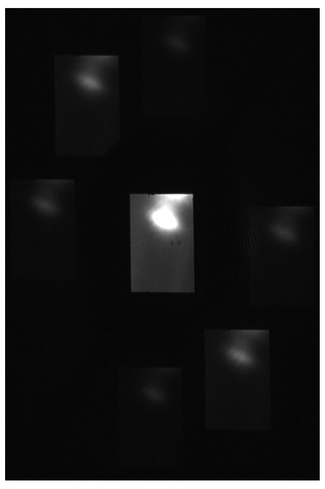

Spectropolarimetry of the solar spicules in Hα and D3 spectral lines using the 53-cm coronagraph of the Abastumani Astrophysical Observatory

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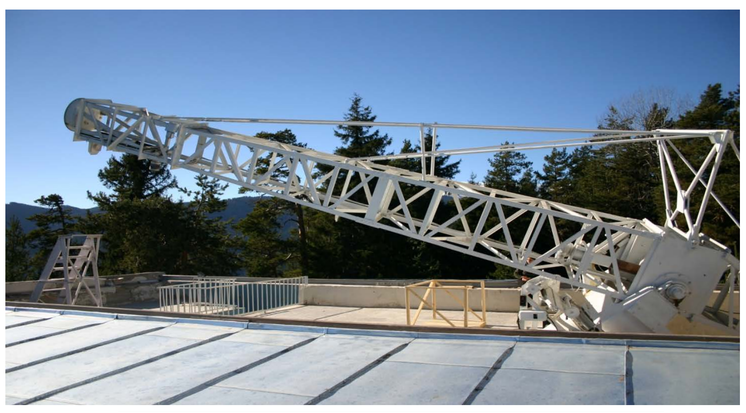
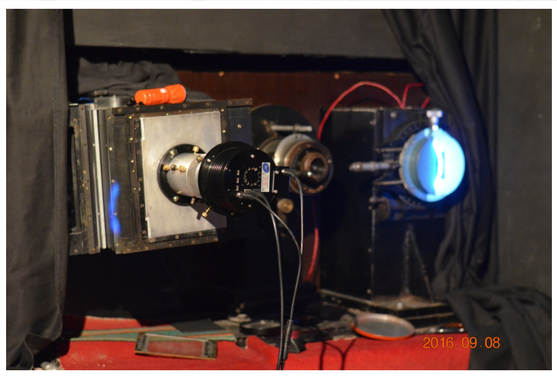
INTRODUCTION

The solar spicules are thin and very dynamic needle-shaped plasma jet structures, the best seen at the solar limb, whose magnetic properties are not well constrained to date. The magnetic field in spicules has been determined using direct analyses of spectral lines in polarized light, mostly using the He I spectral multiplets. The polarization signals in these multiplets are generated by the joint action of the transversal Zeeman effect and scattering polarization modifed by the Hanle effect.

Here we present the test results of the spectro-polarimetry of the spicules in the Hα and He I D3 multiplet for different chromospheric altitudes using the innovative Polarization-Holographic Imaging Stokes Polarimeter (PHISP) mounted on the 53-cm coronagraph of the Abastumani Astrophysical Observatory.

The polarization-holographic method was first proposed by Prof. Sh.Kakichashvili in 1972. It allows to create a unique polarization-holographic optical element capable to make a full analysis of polarization state in a real time and in a wide spectral range including near infrared. Such element is a main optical part of PHISP.

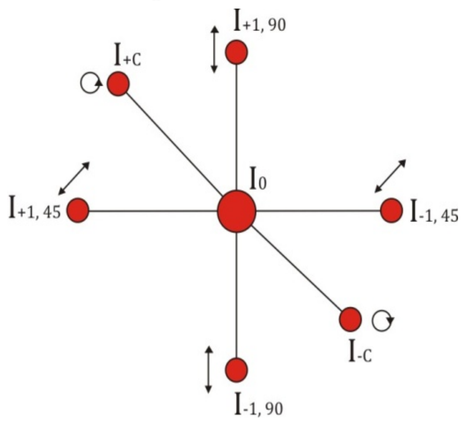




The PHISP equipped with the Starlight Express Trius SX-36 CCD and mounted at the spectrograph (lower image) of the 53-cm coronagraph (upper image) of Abastumani Astrophysical Observatory.

METHOD & DESIGN

In the process of diffraction, the element decomposes light into orthogonal circular and linear basis. As a result the element forms two orthogonal circularly polarized beams with intensities I_{+C} and I_{-C}, two linearly polarized beams with an azimuth +45°, two linearly polarized beams *w*ith an azimuth +90° with intensities I_{45} and I_{90} correspondingly and also none diffracted beam with a state of polarization identical to incoming beam.



The general configuration of diffraction orders

Simultaneous measurement of the intensities of the diffracted beams allows to determine all four Stokes parameters and the corresponding parameters of the polarization ellipse

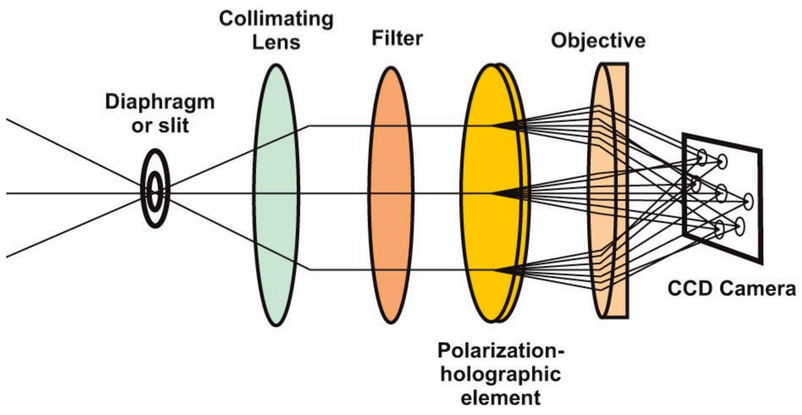
$$I = k_{+C} \cdot I_{+C} + k_{-C} \cdot I_{-C}$$

$$Q = I - 2k_{90} \cdot I_{90}$$

$$U = 2k_{45} \cdot I_{45} - I_{\lambda}$$

$$V = k_{+C} \cdot I_{+C} - k_{-C} \cdot I_{-C}$$

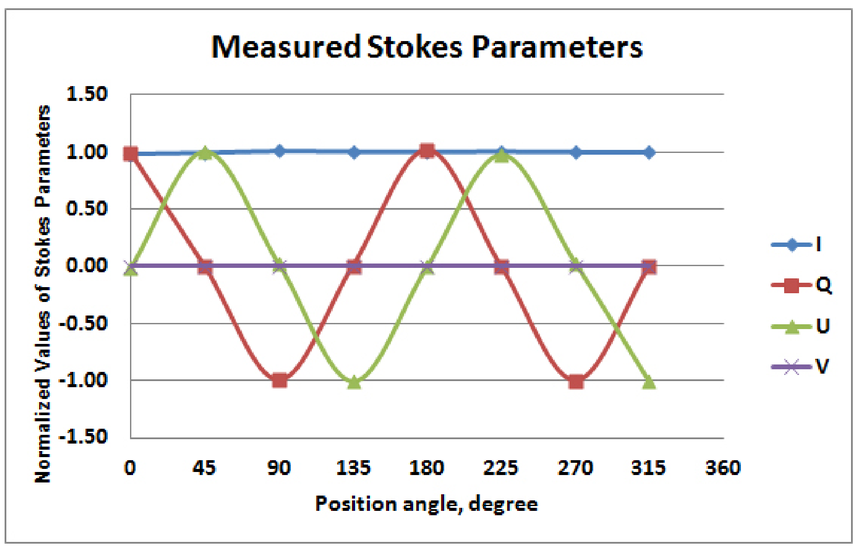
where *k* terms are coefficients connected with absorption of a light in an element, diffraction efficiency of an element and the optoelectronic transformations by the photo-detectors. The values of these coefficients are determined experimentally during calibration. The operating spectral range of an element varies between 500-1600 nm with diffraction efficiency equal to 20% at 532 nm, 16% at 635 nm and 2% at 1550 nm. The diffraction gratings have 330 lines/mm density and spectral dispersion of about 70 nm/mm.



The principal schema of PHISP

CALIBRATION

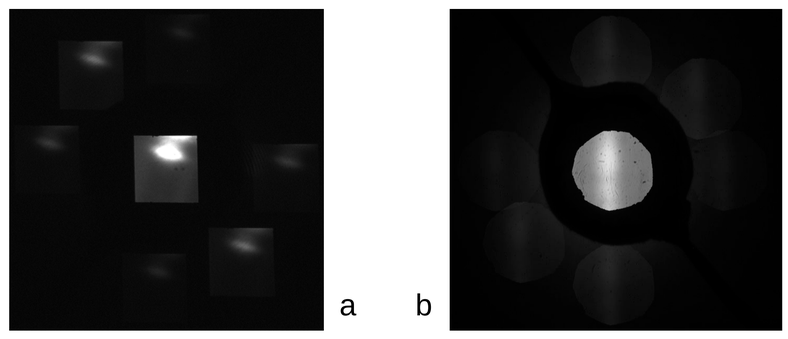
For calibration purposes the special spectropolarimetric observations of the solar photosphere were carried out in Hα and D3 absorbtion lines immediately after the observations of the spicules with identical setup of the telescope and the polarimeter. The polarizer were placed in front of the spectrograph slit and rotated by 45 degrees to obtain linear polarization light beam with different phase angles. The image processing and data retrieval procedures were the same as for the spicule images. The spectral line minimums were used to calculate the calibration parameters. The measured intensities and known values of the Stokes parameters of every position of the polarizer were used in the formulas above to calculate the calibration coefficients.



The results of calibration measurements: variation of normalized Stokes parameters with position angle of linearly polarized light

TEST OBSERVATIONS

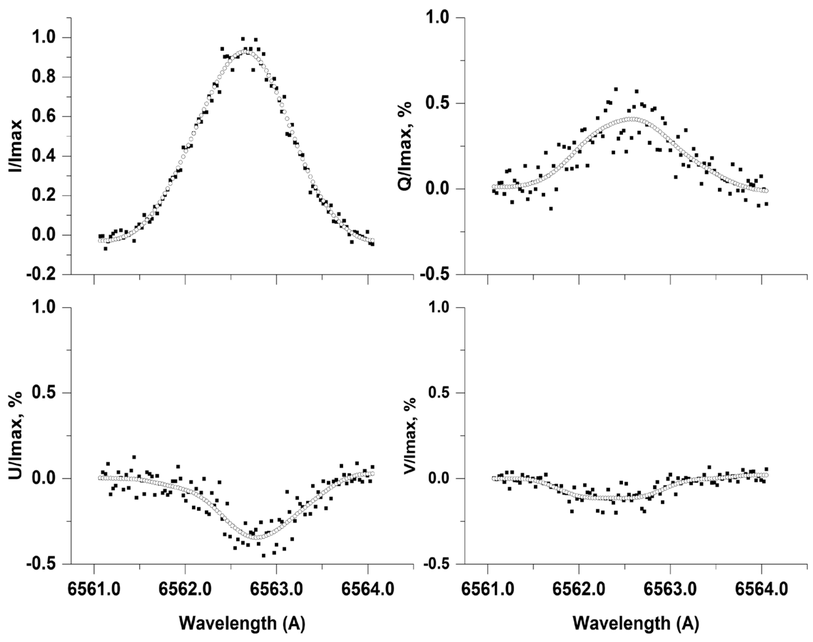
The polarization-holographic images of Hα and D3 spicules were obtained during 2017 using 53-cm coronagraph equipped with spectrograph having spectral dispersion of 0.96 Å/mm on different heights from the solar limb: 5000-7000 km.



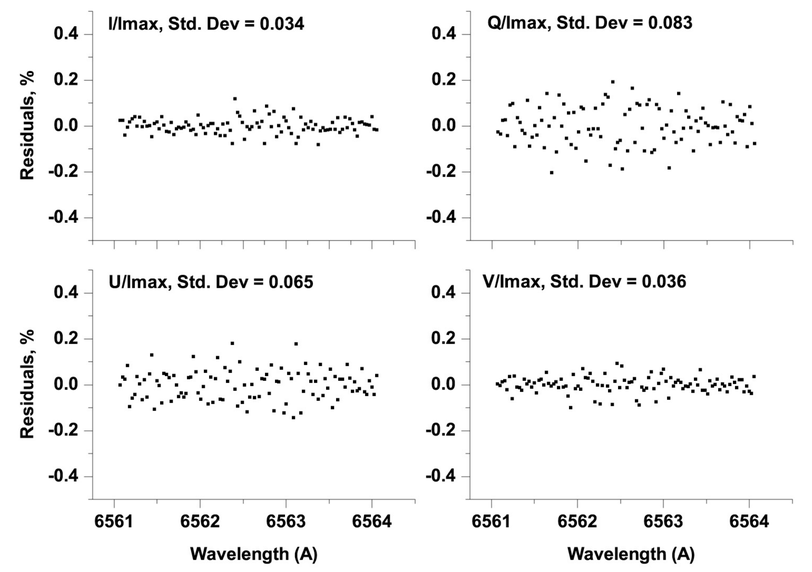
Polarization-diffraction Images of Spicules in Hα (a) and He I D3 (b). Spectral dispersion is aligned horizontally. The orthogonal direction is parallel to the solar limb. Different shapes of entrance diaphragm were used. The exposures were 10 sec for Hα and 5 sec of D3.

TEST RESULTS

The intensity profiles of the spicules were transformed to the Stokes profiles using the calibration coefficients. The resulting normalized Stokes profiles are depicted below. Also fitted curves are shown which are calculated using spline algorithm. The residuals between measurements and fitted curves show that the errors are better than 10^{-3}.



Observed Hα Stokes profiles. The Stokes parameters are normalized to I_{max} value.



Residuals between observed Stokes profiles and fitted profile curves. Standard deviation are indicated for each Stokes profile.

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